Journal of Rehabilitation Sciences and Research

JRSR

Review Article

A Systematic Review of Speech Recognition Assessment Tools for Persian-speaking Children with and without Hearing Disorders

Mohammad Majid Oryadi-Zanjani[1,2*], PhD

[1]Department of Speech Therapy, School of Rehabilitation Sciences, Shiraz University of Medical Sciences, Shiraz, Iran
[2]Rehabilitation Sciences Research Center, Shiraz University of Medical Sciences, Shiraz, Iran

ARTICLE INFO

Please cite this article as:
Oryadi-Zanjani MM. A Systematic Review of Speech Recognition Assessment Tools for Persian-speaking Children with and without Hearing Disorders. JRSR. 2022;9(4):143-150.

ABSTRACT

Background: Speech recognition is a significant component of speech perception assessment as a main clinical target in children with hearing disorders. The current article presents a systematic review designed to provide clinical and research guidelines for speech recognition assessment in Persian-speaking children with and without hearing disorders.
Methods: A systematic search was conducted to cumulate the research evidence for the assessment of speech recognition in Persian-speaking children with and without hearing disorders. Peer-reviewed journal articles dedicated to this issue and published between 1982 and December 2021 were discovered through a search of the electronic databases of PubMed, Scopus, MEDLINE, Web of Science, Magiran, IranMedex, Scientific Information Database (SID), and Google Scholar. The papers were analyzed according to different variables, including test age, vocabulary competency, cognitive demands, response format, presentation mode, stimulus format, stimulus variability, stimulus mode, and test conditions.
Results: The review identified four papers related to the development of five assessment tools for measuring speech recognition in Persian-speaking children, namely Persian Monosyllabic Lexical Neighborhood Tests (PMLNTs), Persian Disyllabic Lexical Neighborhood Tests (PDLNTs), Persian version of the words-in-noise (WIN), Tavana (test for evaluating auditory skills), and closed-set speech recognition test for Persian-speaking children. The properties and limitations of each test have been considered in the current review article.
Conclusion: Based on this systematic review, only four speech recognition assessment tools exist for measuring specifically spoken word recognition in Persian-speaking children. The results of this review article can be used as a clinical and research guideline for assessing speech recognition in Persian-speaking children with hearing disorders.

Background

To perceive speech, four essential auditory skills should be hierarchically executed: detection (knowing if sound is present or absent), discrimination (knowing whether sounds are identical or different), identification/

recognition (knowing what the sound is), and comprehension (understanding what the sound means) [1]. Furthermore, developmental deficiency in each level of auditory processing caused by hearing disorders can result in language, speech, social, and/or academic problems in children [2-5]. Accordingly, to enhance auditory-verbal skills in children with hearing disorders, clinicians, including speech-language pathologists and audiologists, should accurately identify any underlying deficits in the various levels of the auditory

Corresponding author: Mohammad Majid Oryadi-Zanjani, PhD; Department of Speech Therapy, School of Rehabilitation Sciences, Abiverdi1, Chamran Blvd., P.O. Box: 71345-1733, Shiraz, Iran. **Tel:** +98 9171894043; **Email:** oryadim@gmail.com

processing of speech [6]. Moreover, they must regularly assess children's speech perception to monitor their auditory skills improvement [7-9]. Although cochlear implantation (CI) assists children generally in achieving age-appropriate abilities in speech perception [10-13], spoken language skills [13-16], and opportunities in mainstream educational settings [17, 18], its outcomes vary among children, and the majority of users continue to be challenged by speech-in-noise perception [1, 19-21]. Therefore, researchers and clinicians who work with pediatric cochlear implant (CI) users have two main goals: (I) to determine factors related to variations in user performance [22], and (II) to develop interventional approaches to improve the outcomes of users who have inappropriate performance [23]. As a result, speech recognition, the most fundamental outcome of CI that plays an essential role in the development of language, speech production, and literacy skills, forms the core of investigations. Accordingly, the measurement of speech recognition as a main clinical target is a significant component of speech perception assessment in children with CI [1, 6]. To predict how a child with hearing disorders can later achieve language proficiency, speech, literacy, and cognitive skills, however, it is essential to measure speech perception by a set of tests [1, 6].

Indeed, several factors affect speech perception performance as well as the validity and reliability of pediatric speech perception procedures which can be divided into two main categories: (a) internal factors related to the subject's character, such as chronological age, vocabulary competency, and cognitive abilities; and (b) external factors outside the subject, such as appropriate response task, the utilization of reinforcement, the reduction of memory load inherent in the task [6], and stimulus mode (auditory-only or audiovisual modality) [24, 25]. As there is no definitive protocol for assessing speech recognition in Persian-speaking children with and without hearing disorders, knowing the characteristics of the available assessments can be clinically effective in selecting and using them accurately and also in developing more efficient assessment tools.

The current article presents a systematic review designed to provide clinical and research guidelines for the speech recognition assessment of Persian-speaking children with and without hearing disorders. This systematic review aims to: (I) provide a summary and evaluation of speech recognition assessment tools described in the literature that have been used with Persian-speaking children with hearing disorders; (II) consider core components that clinicians should use for an evidence-based speech recognition assessment of Persian-speaking children with hearing disorders; and (III) present some recommendations for future research.

Methods

Systematic Search

The protocol for this systematic review study was approved by the Ethics Committee of Shiraz University of Medical Sciences, Shiraz, Iran (IR.SUMS.REC.1399.538).

The review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [26]. These guidelines, in particular the PRISMA flow diagram, were used to improve the transparency and quality of reporting (Figure 1).

Identification: A systematic search was conducted to cumulate the research evidence for the assessment of speech recognition in Persian-speaking children with hearing disorders. Peer-reviewed journal articles were identified by searching the electronic databases of PubMed, Scopus, MEDLINE, Web of Science, Magiran, IranMedex, Scientific Information Database (SID), and Google Scholar.

Keywords used were "child" or "infant" or "toddler" AND "hearing" or "speech" or "cochlear" or "noise" or "recognition" or "perception" AND "Persian" or "Iranian" or "Iran" or "Farsi." Specific search terms varied depending on MeSH and the search engine's dictionary of associated terms.

Screening: All references were exported to Endnote X7 (Thomson Reuters, 2014), where of the 1297 imported papers, 653 duplicates were removed, leaving 644 for further analysis. Due to the broad nature of the initial
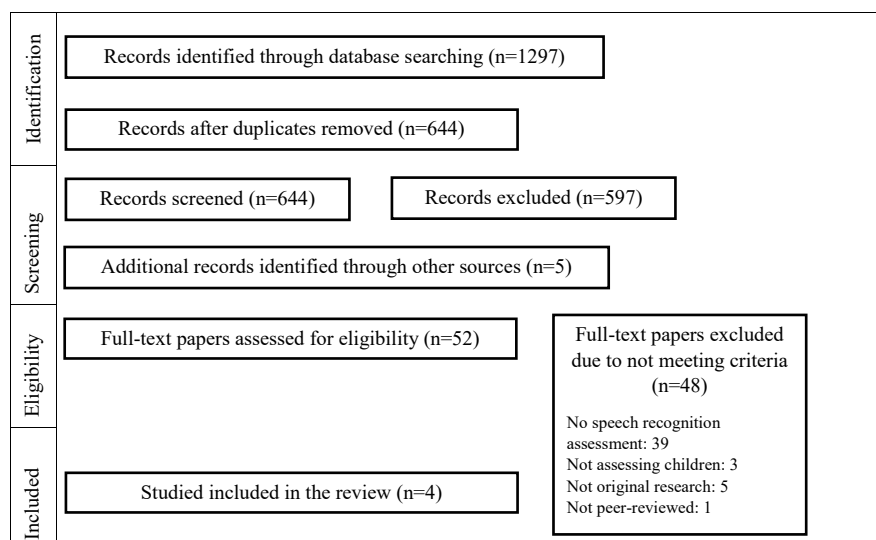
Figure 1: Flow diagram of study selection (adapted from Preferred Reporting Items for Systematic Reviews and Meta-Analyses; Moher et al., 2009).

search, references were further filtered according to title, abstract, and keywords.

Papers were excluded from this review if they: (a) did not include Persian-speaking children, (b) did not focus, at least in part, on the speech recognition of Persian-speaking children, or (c) did not focus, at least in part, on the speech perception of Persian-speaking children. Of the 644 papers screened, 597 papers were excluded based on these criteria.

Following the initial search, the reference lists of the retrieved papers were hand-searched for additional papers that met the inclusion criteria. An additional three eligible papers were identified through these secondary searches.

Eligibility: Inclusion criteria. The full papers for the selected 50 references were obtained and assessed according to the following inclusion criteria: (a) peer-reviewed papers published between 1982 and December 2021; (b) written in Persian or English; (c) at least one Persian-speaking child assessed; (d) at least one aspect of speech recognition assessed (in format of syllable, word, non-word, sentence); and (e) using formal, informal, or unpublished speech recognition assessment measures. Four papers met the inclusion criteria.

Analysis

All four papers were reviewed by the author and an independent rater and coded according to: (1) test age, (2) vocabulary competency, (3) cognitive demands, (4) response format, (5) presentation mode, (6) stimulus format, (7) stimulus variability, (8) stimulus mode, and (9) test conditions.

Test Age

It is not feasible to measure spoken word recognition using behavioral tests in children less than 3 years of age due to developmental issues; however, parent report scales can be used to assess children's auditory skills generally in early ages [1, 6]. Accordingly, the chronological ages which can be used in each assessment were categorized as three periods: the establishing language (early ages: under 3 years old), developing language (preschool ages: 3 to 6 years old), and developed language (school ages: 6 to 12 years old) periods.

Vocabulary Competency

Children with hearing disorders usually have a restricted lexicon because of language development delays. Accordingly, the assessment of speech recognition can be a challenging situation if words used in a test are unfamiliar to the subject. Therefore, each test must be lexically suitable for children [1, 6].

Cognitive Demands

Speech recognition can be indirectly measured simply by considering a child's responses. If the child cannot understand a task or cannot attend to it due to intellectual or attention deficit, the subject's observed performance may be estimated as significantly less than their actual speech recognition abilities [1, 6, 7].

Response Format

Considering whether a test provides an unlimited number of response possibilities or not, tests can be divided into two main categories: open-set tests and closed-set tests, one of which can be used depending on the listener's capabilities and the aim of the assessment. As a general rule, if the listener has sufficient speech production, an open-set test can be an appropriate choice. Otherwise, the picture discrimination test, as a closed-set test, can be useful, because the listener does not need to make either a spoken or a written response. Therefore, as performing an open-set test demands storing and retrieving target items independently from lexical memory, it may be a convenient tool to assess a child's performance in natural situations [1, 6]. Closed-set tests may be more developmentally appropriate for very young children, because they have a more straightforward response format [27].

Presentation Mode

Using recorded instead of live voice presentation of test materials has an important benefit, which is to maintain consistency in presentation either from one listener to the next or from one administration to the next in the same listener. Therefore, it is emphasized that speech recognition assessment should be administered using recorded stimuli so as to improve the reliability of the outcomes [1, 6].

Stimulus Format

To measure speech perception, the complexity of linguistic context can be hierarchically categorized as syllables/non-words, words, sentences, and connected speech based on perceptual levels from "bottom-up" to "top-down" processing [1]. To assess speech recognition specifically, however, the stimulus format can be phonemes, syllables, isolated words, and words-in-sentences [28, 29].

Stimulus Variability

Traditional word-recognition tests usually use word lists that are (a) phonetically balanced (PB), and (b) produced by one talker at one speaking rate. As natural listening conditions involve many sources of stimulus variability, the results of these tests may not adequately estimate the perceptual processes used to perceive speech under natural conditions [29]. Accordingly, researchers have investigated the effects of lexical difficulty ("easy" words versus "hard" words), word length (monosyllabic words versus multisyllabic words), and talker conditions (single-talker versus multiple-talker) as three sources of stimulus variability affecting word-recognition performance. "Easy" words include words that occur frequently and have few phonemically similar neighbors, and "hard" words include words that occur infrequently and have many similar neighbors. According to the previous findings, word-recognition performance was significantly higher in lexically "easy" words than lexically "hard" words, multisyllabic words than monosyllabic words, and single-talker conditions than multiple-talker conditions as well [29-31].

Stimulus Mode

As an auditory-visual event, speech is optimally perceived under audiovisual processing in children with and without normal hearing. Accordingly, it was recommended that the assessment of children's speech perception be conducted in both auditory-only and audiovisual formats [16, 24, 25, 32].

Test Condition

Competing noise, reverberation, and listener distance from the sound source are three essential factors that interfere with speech processing by degrading the primary acoustic speech signal. In conclusion, speech recognition can be more challenging when assessment is executed in spectrally and temporally degraded conditions [6].

Results

The current review identified four papers that met the inclusion criteria. A four-phase flow diagram adapted from PRISMA guidelines [26] outlines the study selection process (Figure 1).

All four papers were related to the development of assessment tools to measure speech recognition in Persian-speaking children. As seen in Table 1, a total of 5 tests were analyzed: Persian Monosyllabic Lexical Neighborhood Tests (PMLNTs) [33], Persian Disyllabic Lexical Neighborhood Tests (PDLNTs) [33], Persian version of the words-in-noise (WIN) [34], Tavana (test for evaluating auditory skills) [35], and closed-set speech recognition test for Persian speaking children [36]. Test characteristics are reported below.

Closed-set Speech Recognition Test

According to Table 1, as a PB test, the closed-set speech recognition test includes 4 lists each comprising 25 monosyllabic words selected from the common objective vocabulary of children in the age range to assess specifically speech recognition in 4-to-6-year-old Persian-speaking children. The child must listen only to a spoken word presented as a recorded voice and then select the correct picture among three pictures related to three similar words. Although using picture pointing as a response method can facilitate a child's performance of the task by lowering the load of working memory, it demands the child's comprehension abilities be used

Table 1: The characteristics of each test based on the different variables

Test	Subtests	Test age	Linguistic competency	Cognitive demands	Response format	Presentation mode	Stimulus format	Stimulus variability	Stimulus mode	Test condition
Persian Monosyllabic Lexical Neighborhood Tests[a] (PMLNTs)	PMLNT-easy PMLNT-hard	6-12 year	Lexically adjusted for children Independent to linguistic ability	High loading on working memory	Open-set Repetition	Recorded voice Sound field	Monosyllabic words Easy word list: 18 items Hard word list: 18 items	Lexically controlled words (easy, hard) Single-talker (female)	Auditory	Competing noise
Persian Disyllabic Lexical Neighborhood Tests[a] (PDLNTs)	PDLNT-easy PDLNT-hard	6-12 year	Lexically adjusted for children Independent to linguistic ability	High loading on working memory	Open-set Repetition	Recorded voice Sound field	Disyllabic words Easy word list: 27 items Hard word list: 27 items	Lexically controlled words (easy, hard) Single-talker (female)	Auditory	Competing noise
Persian version of the words-in-noise[b] (WIN)	Two word lists	7-12 year	Lexically adjusted for children Independent to linguistic ability	High loading on working memory	Open-set Repetition	Recorded voice Headphone	Monosyllabic words 2 lists of 35 items each	Words difficulty in noise (easy, difficult, suitable) Phonetically balanced Single-talker (female)	Auditory	Competing noise
Tavana[c] (test for evaluating auditory skills)	Detection Dis-crimination Identification Comprehen-sion	3-4 year	Lexically adjusted for children Dependent to linguistic ability	Low loading on working memory	Closed-set Picture pointing	Live voice	8 Items of Identification subtest: 3 items of environmental sounds, 2 items of vowels, 1 item of words, 2 items of sentences	None	Auditory	Quiet
Closed-set speech recognition test for Persian speaking children[d]	Four word lists	4-6 year	Lexically adjusted for children Dependent to linguistic ability	Low loading on working memory	Closed-set Picture pointing	Recorded voice Headphone or sound field: Not reported	Monosyllabic words 4 lists of 25 items each	Phonetically balanced Single-talker (female)	Auditory	Quiet

[a] Oryadi-Zanjani et al. (2020); [b] Lotfi et al. (2016); [c] Jarollahi et al. (2010); [d] Adelghahraman et al. (2000)

to understand and remember the meaning of the given word. Otherwise, the child cannot accomplish the recognition task whether or not they can recognize the word. Therefore, it can be concluded that the test is essentially a combined task of speech recognition and speech comprehension.

Regarding psychometric analysis, the test was implemented on 33 Persian-speaking children with normal hearing. No information about the sampling method or the demographic characteristics of the participants was available. The content validity of the test was investigated by surveying a number of experts, and it was reported as about 70% for each word list. Nonetheless, no data on the survey method, number of experts, or their proficiency was available. The test was implemented as test-retest under quiet conditions. No significant difference was observed between the participants' test-retest mean total scores. Furthermore, there was no significant difference among the participants' mean scores on four word lists. It can be concluded that the test had test-retest

reliability and internal consistency (list equivalency) in children with normal hearing. It was also reported that the participants could gain between 92-100 percent of scores in normal sound intensity. There was, however, no information about the performance of children with hearing loss (HL) on the test. Both the properties and the limitations of the closed-set speech recognition test are illustrated in Table 2.

Tavana

As seen in Table 1, Tavana is a comprehensive assessment tool for evaluating auditory skills in 3-to-4-year-old Persian-speaking children that comprises four subtests to assess detection, discrimination, identification, and comprehension [35]. The subtest of identification (recognition) in the test includes eight items to recognize different stimuli, namely environmental sounds (3 items), vowels (2 items), words (1 item), and sentences (2 items). Considering its items, it seems that this test can be suitable for screening goals. That is, to determine a

Table 2: The properties and limitations of each test

Test	Properties	Limitations
Persian Monosyllabic Lexical Neighborhood Tests[a] (PMLNT-easy, PMLNT-hard) Persian Disyllabic Lexical Neighborhood Tests[a] (PDLNT-easy, PDLNT-hard)	Specific for spoken word recognition assessment Suitable for 6-to-13-year-old children Lexically controlled Data about the performance of children with hearing loss A speech-in-noise test Lexically adjusted for children Phonetically balanced Recorded voice Test-retest reliability Content validity List equivalency Responding by word repetition Free field Applicable for children with hearing loss using hearing aids and/or cochlear implants	Loading on working memory
Persian version of the words-in-noise[b] (WIN)	Specific for spoken word recognition assessment Suitable for 7-to-12-year-old children A speech-in-noise test Lexically adjusted for children Phonetically balanced Recorded voice Test-retest reliability Content validity List equivalency Responding by word repetition	No data about the performance of children with hearing loss Loading on working memory Using headphone
Tavana[c] (test for evaluating auditory skills)	Suitable for 3-to-4-year-old children Lexically adjusted for children Phonetically balanced Live voice Appropriate time of test implementation Low loading on working memory Responding by picture selection	No data about the performance of children with normal hearing No data about the performance of children with hearing loss No data about the test reliability No demographic data related to the participants A screening assessment tool Not specific for speech recognition assessment Overlapping between speech recognition and speech comprehension Just 1 item for word recognition Not applicable as a speech-in-noise test
Closed-set speech recognition test for Persian speaking children[d]	Specific for spoken word recognition assessment Suitable for 4-to-6-year-old children Lexically adjusted for children Phonetically balanced Recorded voice Low loading on working memory Test-retest reliability Content validity List equivalency Responding by picture selection	No data about the performance of children with hearing loss No demographic data related to the participants No data about the survey method for content validity No data about the number of experts and their proficiency Overlapping between speech recognition and speech comprehension Not applicable as a speech-in-noise test No data about using headphone or sound field

[a] Oryadi-Zanjani et al. (2020); [b] Lotfi et al. (2016); [c] Jarollahi et al. (2010); [d] Adelghahraman et al. (2000)

child's speech recognition skills, specifically at the level of word, it may be better to use specific assessment tools. Tavana is a close-set test on which the child can select a desired picture by pointing to, picking up, or looking at the picture as a response to each item of the test presented by an examiner as a live voice. Therefore, it can be a good choice to use for assessing 3-to-4-year-old children, because performance on the test does not require a lot of working memory. However, to answer the task, the child must know the meaning of the desired item in order to select the related picture. Therefore, it can be concluded that the identification subtest of Tavana does not precisely assess speech recognition; rather it measures a combination of speech recognition and comprehension. That is, if a child does not know the meaning of words and sentences or cannot remember them at the time, they cannot respond to the subtest whether or not they can actually recognize the words or sentences.

Additionally, the words used as test items were selected from familiar objective words for children less than 5 years of age with/without HL. The child should receive the items of the test through auditory modality only under quiet conditions. Accordingly, Tavana cannot be used to assess children's speech-in-noise perception skills.

Using live voice can influence a child's performance from one test session to another due to: (a) variations of the examiner's voice quality depending on sex, age, physical health, etc.; and (b) variations of the examiner's voice loudness that cannot be easily controlled in live voice.

As a pilot study, the test was implemented on 5 children with normal hearing and 4 children with HL to investigate its executive problems. No participant demographic data was available; the content validity of its subtests only was studied by asking 7 experts for their views about the items. Therefore, there was no evidence about the reliability of Tavana in Persian-speaking children with HL and their peers with normal hearing. Both the properties and the limitations of Tavana are illustrated in Table 2.

Persian Version of the Words-in-Noise (WIN)

As seen in Table 1, the Persian version of the words-in-noise (WIN) as a PB test was developed to assess speech recognition skill in 7-to-12-year-old Persian-speaking children [34]. It includes 2 lists each comprising 35 monosyllabic words selected from of frequently used words by Persian-speaking children in primary schools. Based on 10 experts, including audiologists, speech therapists, and linguistics, words with a content validity ratio (CVR) higher than 0.62 were selected, and the content validity index (CVI) of each list was higher than 0.8. The confirmed words were recorded by a female speaker in an acoustic studio. To determine the word difficulty in noise, the mean difficulty of the words was determined through a pilot study. Accordingly, all the words were classified in the three levels of easy, acceptable, and difficult. Finally, 70 monosyllabic words were selected and then randomly distributed into 2 lists, each comprising 35 words in 7 signal-to-noise ratios (SNR) decreased by 4 steps.

The test was implemented on 63 Persian-speaking children with normal hearing (36 boys and 27 girls) recruited by convenience sampling from primary school children. The words were presented by headphone to right and left ears at each of 7 SNRs from +24 to 0 dB SNR in 4 dB decrements in babble noise at the constant level of 60 dB. The participants were asked to repeat any word they heard. The retest was carried out by the same examiner on 2 children of each age group (total 12 participants) 2 to 4 weeks after the test. Then, the intraclass correlation coefficient (ICC) was measured to determine test-retest reliability. According to the study findings, there was no significant difference between the mean scores of right and left ears or between boys and girls. Furthermore, a significant correlation was observed between test-retest scores of each list and between test-retest scores of two lists [34]. There was, however, no information about the performance of children with HL using the WIN test. It seems that using headphones to administer the test may be a serious limitation in assessing children with HL because of the child's hearing aid (HA) and/or CI. Both the properties and the limitations of the WIN are illustrated in Table 2.

Persian Lexical Neighborhood Tests (PLNTs)

As seen in Table 1, PLNT is a lexically controlled assessment tool independent of vocabulary and language competency that can be used to measure spoken word recognition (SWR) performance in 6-to-12-year-old Persian-speaking children [33]. The subsets of lexically easy and hard words required Persian-speaking children to be familiar with the words. Thus, a corpus of common words was created based on 461 well documented language samples produced by normal Persian-speaking children aged 2-to-5 years old [37]. To determine the lexical difficulty of words (easy, hard, neutral) based on the Neighborhood Activation Model (NAM) as the model of SWR, it was necessary to calculate word frequencies and neighborhood densities. Word frequency is the occurrence number of a word, and neighborhood density is determined by the number of neighbors that a word has. Ultimately, four lexically controlled word subscales were generated: the Persian Monosyllabic Lexical Neighborhood Test-easy (PMLNT-easy) (5 practice and 18 key words), the Persian Monosyllabic Lexical Neighborhood Test-hard (PMLNT-hard) (5 practice and 18 key words), the Persian Disyllabic Lexical Neighborhood Test-easy (PDLNT-easy) (5 practice and 27 key words), and the Persian Disyllabic Lexical Neighborhood Test-hard (PDLNT-hard) (5 practice and 27 key words). The isolated key words were digitally recorded by a female native speaker of the Persian language under acoustically controlled conditions. The PLNTs were performed in different levels of SNRs, including -2, 0, 2, and 4 dB [33].

The PLNTs were administered on twenty 6-to-12-year-old Persian-speaking children with normal hearing. According to the findings, the participants performed significantly better on SWR using the PLNTs consisting of easy words compared to the PLNTs consisting of hard words and using disyllabic words compared to monosyllabic words. Moreover, the participants'

performance on SWR improved overall with increasing SNR levels. In other words, the Persian-speaking children's performance on SWR is significantly influenced by three important variables: word lexical difficulty, word length, and SNR levels [33].

Furthermore, the PLNTs were used to investigate the effect of lexical difficulty on SWR performance in 7-to-13-year-old Persian-speaking children with HL (test phase: 13 participants and retest phase: 9 participants). According to the findings, word lexical difficulty and word length were the most fundamental factors, having significant effects on the recognition of spoken words in children with HA or CI in the test/retest phases under spectrally degraded conditions [38]. Both the properties and the limitations of the PLNTs are illustrated in Table 2.

Discussion

Based on the findings of this systematic review (Table 1), only 5 assessment tools have been developed to assess speech recognition skills (auditory identification) in Persian-speaking children during more than two decades from 2000 to 2021 [33-36], only 4 of which can be used to specifically measure SWR (Table 2). As a screening assessment tool, Tavana can be used to measure general speech perception skills in 3-to-4-year-old Persian-speaking children [35]. A child who cannot accomplish the identification subtest of Tavana must be assessed using speech recognition tests, such as Persian Monosyllabic Lexical Neighborhood Tests (PMLNTs-easy and PMLNTs-hard) [33], Persian Disyllabic Lexical Neighborhood Tests (PDLNTs-easy and PDLNTs-hard) [33], Persian version of the words-in-noise (WIN) [34], and closed-set speech recognition test for Persian speaking children [36].

As a PB test, the closed-set speech recognition test may be the first assessment tool developed for measuring SWR skill in 4-to-6-year-old Persian-speaking children in quiet conditions [36]. It is recommended to use the test cautiously, because no results of the performance of children using HA and/or CI on it have been reported.

The Persian version of the words-in-noise is a PB test that can be reliably used to measure SWR in 7-to-12-year-old Persian-speaking children in competing noise [34]. It is advised, however, to use the WIN cautiously, because no results of the performance of children using HA and/or CI on it have been reported.

Indeed, when we listen to a word or sentence, each word's acoustic signal automatically connects to its stored representations in our mental lexicon [39]. Accordingly, we can recognize spoken words. Moreover, based on the NAM, the process of SWR is influenced by the structure of the similarity neighborhood [40]. Based on this assumption, the findings of several studies emphasized that the SWR performance of pediatric HA and/or CI users was influenced by the frequency and the neighborhood density of stimulus word similar to their peers with normal hearing [30, 33, 38, 41]. Furthermore, comparing the performance of children using CI on lexically controlled tests and PB word lists indicated that the PB tests underestimates the children' SWR

[41]. Therefore, as the first lexically controlled Persian tests based on the NAM, the PMLNTs (PMLNTs-easy and PMLNTs-hard) and the PDLNTs (PDLNTs-easy and PDLNTs-hard) can be reliably used to assess SWR performance under spectrally degraded conditions in 6-to-13-year-old Persian-speaking children without HL and in children using HA and/or CI [33, 38].

In conclusion, based on the current status of speech recognition assessment tools for Persian-speaking children, it is recommended: (I) to study pediatric HA/CI users' performance on the available tests; (II) to compare pediatric HA/CI users' performances using the tests under auditory-only and audiovisual conditions; and (III) to develop lexically controlled tests for children under 6 years of age.

Conclusion

According to this systematic review, there are just four speech recognition assessment tools for measuring specifically spoken word recognition in Persian-speaking children. Two of them are phonetically balanced tests, and the other two are lexically controlled tests. Furthermore, a number of statements were presented that may be considered in future research studies. The results of this review article can be used as a clinical and research guideline for speech recognition assessment in Persian-speaking children with hearing disorders.

Conflict of Interest: None declared.

References

1. Kirk KI, Hudgins M. Speech Perception and Spoken Word Recognition in Children with Cochlear Implants. In: Young NM, Kirk KI, editors. Pediatric Cochlear Implantation. USA: Springer Nature; 2016. p. 145-61.
2. Holt RF, Lalonde K. Assessing toddlers' speech-sound discrimination. Int J Pediatr Otorhinolaryngol. 2012;76(5):680-92.
3. Moeller MP, Hoover B, Putman C, Arbataitis K, Bohnenkamp G, Peterson B, et al. Vocalizations of Infants with Hearing Loss Compared with Infants with Normal Hearing: Part I – Phonetic Development. Ear Hear. 2007;28(5):605-27.
4. Moeller MP, Hoover B, Putman C, Arbataitis K, Bohnenkamp G, Peterson B, et al. Vocalizations of Infants with Hearing Loss Compared with Infants with Normal Hearing: Part II – Transition to Words Ear & Hearing. 2007;28(5):628-42.
5. Oryadi-Zanjani MM. Production of Infant Scale Evaluation (PRISE) in Persian normal hearing children: A validation study. Int J Pediatr Otorhinolaryngol. 2018;113:76-81.
6. Kirk KI, Diefendorf AO, Pisoni DB, Robbins AM. Assessing speech perception in children. USA: Indiana University, 1995.
7. Robbins AM, Kirk KI. Speech perception assessment and performance in pediatric cochlear implant users. Seminars in Hearing. 1996;17(4):353-69.

8. Oryadi-Zanjani MM, Purdy SC, Vahab M, Rasouli J, Vasfinia M, Lotf E. Translation and Adaptation of the Auditory Behavior in Everyday Life. JRSR. 2015;3:63-7.

9. Oryadi-Zanjani MM, Vahab M, Purdy SC. The Persian Version of the Auditory Behavior in Everyday Life Questionnaire Int J School Health. 2018;5(1):e55952.

10. Mitchell RM, Christianson E, Ramirez R, Onchiri FM, Horn DL, Pontis L, et al. Auditory comprehension outcomes in children who receive a cochlear implant before 12 months of age. Laryngoscope. 2020;130(3):776-81.

11. Koopmann M, Lesinski-Schiedat A, Illg A. Speech Perception, Dichotic Listening, and Ear Advantage in Simultaneous Bilateral Cochlear Implanted Children. Otol Neurotol. 2020;41(2):e208-e15.

12. Cesur S, Yuksel M, Ciprut A. Data logging variables and speech perception in prelingually deafened pediatric cochlear implant users. Int J Pediatr Otorhinolaryngol. 2020;133:110003.

13. Dettman S, Choo D, Au A, Luu A, Dowell R. Speech Perception and Language Outcomes for Infants Receiving Cochlear Implants Before or After 9 Months of Age: Use of Category-Based Aggregation of Data in an Unselected Pediatric Cohort. J Speech Lang Hear Res. 2021;64(3):1023-39.

14. Li G, Zhao F, Tao Y, Zhang L, Yao X, Zheng Y. Trajectory of auditory and language development in the early stages of pre-lingual children post cochlear implantation: A longitudinal follow up study. Int J Pediatr Otorhinolaryngol. 2020;128:109720.

15. Soltaninejad N, Jalilevand N, Kamali M, Mohamadi R. Language therapy outcomes in deaf children with cochlear implant using a new developed program: A pilot study. Int J Pediatr Otorhinolaryngol. 2020;133:110009.

16. Oryadi-Zanjani MM, Hasanzadeh S, Rahgozar M, Shemshadi H, Purdy SC, Bakhtiari BM, et al. Comparing the effect of auditory-only and auditory-visual modes in two groups of Persian children using cochlear implants: a randomized clinical trial. Int J Pediatr Otorhinolaryngol. 2013;77(9):1545-50.

17. Choi JE, Hong SH, Moon IJ. Academic Performance, Communication, and Psychosocial Development of Prelingual Deaf Children with Cochlear Implants in Mainstream Schools. Journal of audiology & otology. 2020.

18. Mukari SZ, Ling LN, Ghani HA. Educational performance of pediatric cochlear implant recipients in mainstream classes. Int J Pediatr Otorhinolaryngol. 2007;71(2):231-40.

19. Zaltz Y, Bugannim Y, Zechoval D, Kishon-Rabin L, Perez R. Listening in Noise Remains a Significant Challenge for Cochlear Implant Users: Evidence from Early Deafened and Those with Progressive Hearing Loss Compared to Peers with Normal Hearing. J Clin Med. 2020;9(5).

20. Lee Y, Sim H. Bilateral cochlear implantation versus unilateral cochlear implantation in deaf children: Effects of sentence context and listening conditions on recognition of spoken words in sentences. Int J Pediatr Otorhinolaryngol. 2020;137:110237.

21. Eisenberg LS, Fisher LM, Johnson KC, Ganguly DH, Grace T, Niparko JK, et al. Sentence Recognition in Quiet and Noise by Pediatric Cochlear Implant Users: Relationships to Spoken Language. Otol Neurotol. 2016;37(2):e75-81.

22. Oryadi-Zanjani MM, Mohammadi T, Mohammadi Z, Vahab M. Predictive Factors of Language Development in Persian-speaking Children Using Cochlear Implants: A Pilot Study. JRSR. 2021;8(3):126-31.

23. Pisoni DB. Speech perception in deaf children with cochlear implants. In: Pisoni DB, Remez RE, editors. The Handbook of Speech Perception. Malden: Blackwell Publishing; 2009. p. 494-523.

24. Oryadi-Zanjani MM, Vahab M, Bazrafkan M, Haghjoo A. Audiovisual spoken word recognition as a clinical criterion for sensory aids efficiency in Persian-language children with hearing loss. Int J Pediatr Otorhinolaryngol. 2015;79(12):2424-7.

25. Oryadi-Zanjani MM, Vahab M, Rahimi Z, Mayahi A. Audiovisual sentence repetition as a clinical criterion for auditory development in Persian-language children with hearing loss. Int J Pediatr Otorhinolaryngol. 2017;93:167-71.

26. Moher D, Liberati A, Tetzlaff J, Altman DG, Group TP. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med. 2009;6(7):e1000097.

27. Frisch S, Meyer TA, Pisoni DB, Svirsky MA, Kirk KI. Using behavioral data to model open-set word recognition and lexical organization by pediatric cochlear implant users. Ann Otol Rhinol Laryngol Suppl. 2000;185:60-2.

28. Holt RF, Kirk KI, Hay-McCutcheon M. Assessing multimodal spoken word-in-sentence recognition in children with normal hearing and children with cochlear implants. J Speech Lang Hear Res. 2011;54(2):632-57.

29. Kirk KI, Pisoni DB, Miyamoto RC. Effects of stimulus variability on speech perception in listeners with hearing impairment. J Speech Lang Hear Res. 1997;40(6):1395-405.

30. Kirk KI, Eisenberg LS, Martinez AS, Hay-McCutcheon M. The Lexical Neighborhood Test: Test-Retest Reliability and Inter-List Equivalency. Indiana: Indiana University, 1998.

31. Kirk KI, Hay-McCutcheon M, Sehgal ST, Miyamoto RT. Speech perception in children with cochlear implants: effects of lexical difficulty, talker variability, and word length. Ann Otol Rhinol Laryngol Suppl. 1998;185:79-81.

32. Kirk KI, Hay-McCutcheon MJ, Holt RF, Gao S, Qi R, Gehrlein BL. Audiovisual Spoken Word Recognition by Children with Cochlear Implants. Audiol Med. 2007;5(4):250-61.

33. Oryadi-Zanjani MM, Zamani A. Development of Persian Lexical Neighborhood Tests. Int J Pediatr Otorhinolaryngol. 2020;139:110406.

34. Lotfi Y, Salim S, Mehrkian S, Ahmadi T, Biglarian A. The Persian version of words-in-noise test for young population: development and validation. Auditory and Vestibular Research. 2016;25(4):194-200.

35. Jarollahi F, Modarresi Y, Keyhani MR. Content validity of Tavana: a test for evaluation of auditory skills of 3-4 year-old hearing-impaired Persian children. Audiol. 2010;19(1):11-22.

36. Adelghahraman M, Modaresi D, Sedaei M, Babei D. Development, Standardization and Evaluation of A Close-set Speech Recognotion Test For Persian Speaking Children of 4 to 6 Years old. Bimonthly Audiology-Tehran University of Medical Sciences. 2000;8(1):14-9.

37. Zanjani MMO, Vahab M, Karimi L. Comparing "Mean Length of Utterance" and "Mean Length of Five Phrasal Utterances" between 2-To-5 Year-Old Normal Farsi-Speaking Children. JRSR. 2014;1:52-5.

38. Oryadi-Zanjani MM, Vahab M. Lexical effects on spoken word recognition in children with hearing impairment: Test-Retest Reliability of the Persian Lexical Neighborhood Tests. Journal of Rehabilitation Sciences & Research. 2021;8:169-75.

39. Weber A, Scharenborg O. Models of spoken-word recognition. WIREs Cogn Sci. 2012;3:387–401.

40. Luce PA, Pisoni DB. Recognizing Spoken Words: The Neighborhood Activation Model. Ear Hear. 1998;19(1):1-36.

41. Kirk KI, Pisoni DB, Osberger MJ. Lexical effects on spoken word recognition by pediatric cochlear implant users. Ear Hear. 1995;16(5):470-81.